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THE CAUSE OF COMPLICATIONS: UNDERSTANDING THE RELATION BETWEEN POST-OPERATIVE COMPLICATIONS AND THE SYSTEMS AND PROCESSES OF A HOSPITAL BY MEANS OF AN INFLUENCE DIAGRAM

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Author biography Rien L. Kooistra received his Master's degree in Mechanical Engineering, specializing in Systems Engineering, from the University of Twente in The Netherlands in 2012. Currently, he is pursuing a Professional Doctorate in Engineering in Hospital Engineering at the University of Twente and the ZGT Hospitals. This education focuses on the building-related systems in hospitals and application of Systems Engineering methods in this sector.

Abstract Care for the patient is the core process of hospital care. Hospitals are becoming ever more complex and it is increasingly difficult to have a good overview of the hospital to ensure the quality of care. Among others, additional quality assurance and validation is required to remain in control of the situation. To acquire insight into the most important parameters in patient care, an influence diagram is made of the patient treatment process in the operating room. The outcome of this approach is an extensive diagram, giving an overview of the influences on post-operative complications in a hospital. Based on this, a concise abstraction is made, in which the occurrence of post-operative complications is summarized using a simple system diagram. The main challenges within the current system are identified, and will be used for further research. Preliminary solutions follow from the influence diagram: the essential parameters and the complex interrelations between these parameters are described.

Introduction

Hospitals are complex environments and are expected to become ever more complex. This is mainly due to technological progress and the increasing demands for greater quality and cost-efficiency. With this increasing complexity, it becomes harder to have an overview of the totality of the hospital systems and processes. The main objective has to be kept in mind: providing high quality care for the patient. Instead, attention is often focused on aspects such as technical possibilities or adherence to norms and rules set by external parties.

This paper aims to bring the focus back to the main objective. It gives insight into the way in which a hospital is set up to achieve this objective. This is done by means of an influence diagram. This diagram shows the parameters of influence on one of the key indicators of quality of care: the incidence of post-operative complications after a hospital treatment. Several complications are recognized; post-operative wound infections (POWIs), electrical shock, mechanical damage, failure of medical treatment and succumbing of the patient due to treatment.

Research background

The diagrams are made in order to explore the effects that building-related hospital systems have on patient care. To date, little research has been done in this specific area. Therefore, it is useful to start off with a high-level description, both to explore the range of the discipline and to investigate the main difficulties faced by the discipline. This is echoed by (Blessing and Chakrabarti 2009), who name this first stage of the research process the ‘Research Clarification Stage’. The goals of the research are identified during this stage. The outcome of this first stage is then used as the basis for the remainder of the project. One of the main activities followed by the authors is the creation of influence diagrams which they term ‘reference and impact models’.

The outcomes of the research presented in this paper are used to initiate a research project into building-related hospital systems and the standardization of medically used hospital rooms (Kamp et al. 2014). Building-related hospital systems include systems such as the medical gas network and the electricity network, and may be seen as the infrastructure of the hospital. As such, they share a number of infrastructure properties such as being connected to a large number of other systems, supporting the production of goods and services and being critical to their users as rigorous changes to the system are not possible. This means that the building-related systems are connected to most other hospital systems, and often lead to complex interactions.

The research is carried out within the ZGT hospitals in Hengelo and Almelo, the Netherlands. Together, these two medium-sized hospitals form one of the largest hospital groups in the Netherlands, with a total of 3,200 employees and serving a population of around 300 000 people. In recent years, there has been increasing attention to the technology used in hospitals. The ZGT is a leading hospital in the field of medical equipment safety and is now focusing attention on the hospital building, including the installed medical systems. This is shown by a (Dutch) publication the title of which translates as ‘The hospital is a single large machine’ (Boeke et al. 2010) and by the establishment of an education programme aimed at understanding the building related systems in a hospital.

Method

The main tool used for our analysis of the hospital systems is the influence diagram, a tool proposed by Ross Shachter (Schachter 1986). An influence diagram contains nodes containing either a decision, a probabilistic variable (with unknown value), a general variable (with known value), or an objective. Nodes can be connected by means of links, signifying that they have influence on each other. This leads to insight into the essential elements in a system and their influence on each other. Figure 1 shows a simple example influence diagram and the types of nodes.

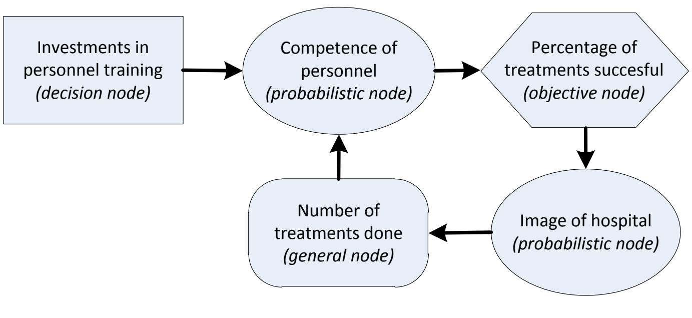

Figure 1. Example of a simple influence diagram with different node types (based on Schachter’s approach)

The influence diagram created contains highly uncertain information at a high level and is thus unsuitable for statistical analysis: patients cannot describe exactly how they feel, doctors cannot predict the exact influence of medicine or surgery, etcetera (Szolovits 1995). It is thus intended mainly to gain an overview of the factors involved, the main categories and, to a certain extent, the importance of all the factors. Therefore, the exact approach is, as also suggested by Schachter (Owens, Schachter, and Nease 1997) 'governed by convenience'. Several changes have been made to Shachter's original approach. Figure 2 gives an overview of item types used. A distinction is made between the items adjustable by different groups of hospital personnel. For example, the outdoor temperature cannot be controlled by anyone, the cleanness of the personnel's hand can be influenced by the medical personnel, and the OR (operating room) temperature setting can be influenced by both the technical and medical personnel.

The diagram is created based on research and stakeholder input. It is kept in mind that the goal is not to be complete but rather to gain insight and overview. Step-wise improvement of the diagram is done using the approach defined by (Borches and Bonnema 2010), which iteratively repeats three steps: Information extraction → abstraction → presentation.

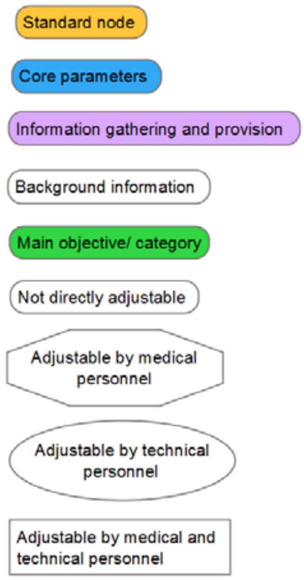

Figure 2. Legend of influence diagram items

Results

The resulting influence diagram is too large to be displayed in this paper. Therefore, an impression is displayed in Figure 3. The complete diagram can be downloaded from http://goo.gl/3M7RCQ . The diagram is best read by starting from the large objective node in the bottom right of the image, and moving outward to the influences on that node. As mentioned, a legend of item types is shown in Figure 2.

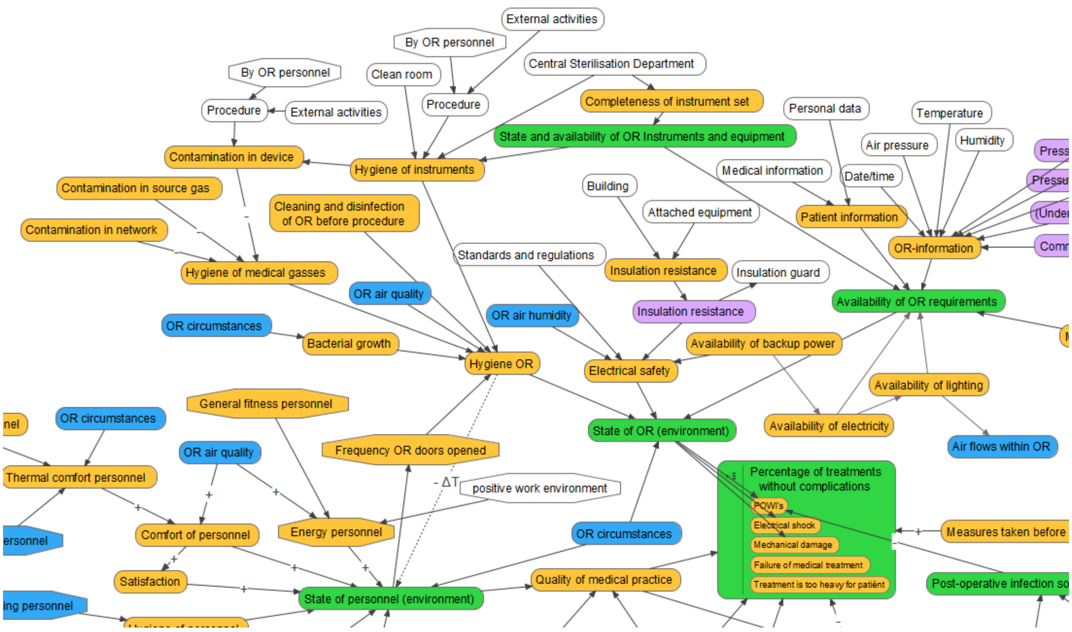

Figure 3. Impression of the created influence diagram

Influences on the core process – the percentage of post-operative complications – are categorized in four main groups:

- the state of the OR
- the state of the personnel,
- the state of the patient and
- the type of procedure being followed.

(Parush et al. 2011) confirm the core items as defined in the diagram, although this source groups the OR and personnel together as 'environment' and adds 'time' as a central item. This paper also recognizes time as one of the key parameters, as further described below.

Expansion of the influence diagram shows that several parameters keep recurring. These parameters influence the core process in many ways. The following key parameters have been identified:

- Duration of procedure (time)
- Clothing worn by personnel
- OR circumstances
    - OR temperature
    - OR air humidity
    - OR air quality
    - Air flows within OR
        - Quality of air blown on patient

Discussion

A single parameter may have influence on many different other parameters. For example, the temperature influences –among other factors– the comfort of both patient and personnel, air humidity and bacterial growth. This means that changing this node alters the objective node in several quite different ways. In other words: it has a complex influence on the objective node. Yet this range of effects also means that the parameters are likely to have a significant influence on the objective node. Making an accurate estimation of this influence is difficult and requires extensive research.

Another problem identified in the influence diagram is that the item measured is not always the parameter of interest. In ORs, the overpressure of the room relative to the outside pressure is measured, while this is not the required parameter. The required parameter is knowledge about whether the required outward flow of air is intact, preventing micro-organisms and other pollutants from entering the room. This may lead to errors when indirectly related parameters are altered, since the exact effect on the objective parameters is not known. One example is that Dutch regulations, in a policy valid from 2001 till 2013 (Overheid 2001), state that an OR must have a fresh air ventilation rate of 20 times the volume of the room per hour. This was set in order to keep the level of nitrous oxide exhaled by the patient below 25% of the Maximal Accepted Concentration (MAC) and was based on the size of the OR. ORs have greatly increased in size, while the amount of nitrous oxide applied has reduced greatly in recent years in view of the perceived risks. Thus, we consider the current approach to be out of proportion for the current ORs.

In short, regulation has been surpassed by developments, but is still in place. A certain amount of air ventilation is required for other reasons, but no research has been undertaken into the optimum amount required.

Abstraction

In summary, the main priority in achieving the objective of minimizing the number of post-surgical complications is in maintaining the critical parameters at their optimums. Widely used cyclic models such as DMAIC (Define-Measure-Analyze-Improve-Control), LAMDA (Look-Ask-Model-Discuss-Act) and FOCUS-PDCA (Find-Optimize-Clarify-Uncover-Start-Plan-Do-Check-Act) all present process improvement approaches. The present paper, however, discusses how the current quality level is assured by analysing what influences the current quality. Quality assurance can thus be captured in a simple cycle, as shown in Figure 4. The figure shows the main points in bold font and some examples in normal font. A system will achieve its goal when these cycles are clear and all points are taken into account.

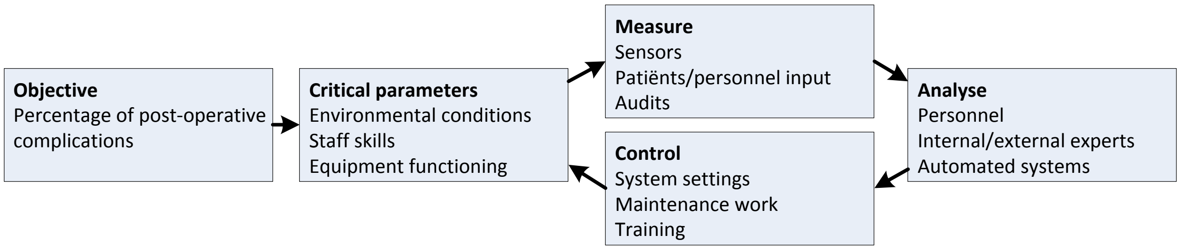

Figure 4. Generalization of the quality assurance cycles found in the influence diagram

Conclusions

Examples have shown that, currently, there is not enough insight into control cycles within the process. Parameters have complex interactions and are often based on outdated objectives which are proven to work, but are not optimal in the current set-ups.

This paper attempts to give insight into the critical parameters that should be measured and governed by the control loop shown in Figure 4. The figure also raises a number of questions which are yet to be answered. An overview of questions raised is given. Italic font indicates questions (partially) answered by the influence diagram:

- How to minimize the percentage of post-operative complications?
    - *What are the critical parameters?*
    - What are the optimum values of the critical parameters?
        - What is the origin of values required by regulations?
    - *What measurable parameters need to be measured in order to accurately estimate the critical parameters' current values?*
    - *What parameters need to be controlled in order to accurately control the critical parameters?*
        - What changes to make to controllable parameters in order to achieve the required optima?
        - *What are the side effects of changing these parameters?*
        - What are the limiting factors in controlling the parameters?

Future work

The exploration into the systems in hospitals and the relation of these systems with the health care process described in this paper has achieved its main goal: creating an overview of the area of building-related hospital systems and their interrelations.

The insight provided by the influence diagrams is used as a starting point for further research into the relation between building-related systems of the hospital and the medical processes within the hospital. The influence diagram is used both as a means to analyse the processes within the hospital and to communicate with stakeholders regarding possible research topics. One such research topic, as mentioned before, which we are currently working on is the standardization of medical rooms (Kamp et al. 2014).

These research topics will involve clarification of the control cycles and investigation into the objectives governing these control cycles.

Acknowledgements

The authors would like to thank all who participated in brainstorm sessions regarding the contents of the influence diagram: Michaël Lansbergen, Petra Brummelhuis, Theo Weijmans, Jetze Posthuma, Irene ten Seldam and Erik Ankersmid. Furthermore, the creators of the tool VUE (http://vue.tufts.edu) are thanked for making the application freely available.

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